Progress report (04/01/2009 – 03/31/2010)

Title: Development of an Extended and Long-range Precipitation Prediction System over the Pacific Islands

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Objective: *Our goal is to develop and transition a dynamical precipitation prediction system for all U.S. Affiliated Pacific Islands (USAPI) based on the CFS.*

2. Results and Accomplishments:

In the last one year, the 15-member ensemble retrospective forecasts (hindcasts) performed with the NCEP Climate Forecast System (CFS) for the period 1982-2005 were assessed for seasonal prediction skills over the tropics, both from deterministic (anomaly correlation, ACC) and probabilistic [Heidke Skill Score (HSS) and Rank Probability Skill score (RPSS)] perspectives. The skill measures were computed for all the four seasons, and for leads ranging from 0 to 6 months. In addition, diagnostics such as persistence correlation, root-mean-square-error, signal to noise ratio and composites were also analyzed. We repeated the diagnostics for verifying the real-time forecast performed by CFS for the period 2006-09.

For the target regions over the USAPI, the current operational seasonal precipitation prediction system is based on empirical methods (e.g., Canonical Correlation analysis or CCA). In CCA prediction tool sea surface temperature (SST) provide the most reliable predictive information, and higher prediction skill is for ENSO winters. For non-ENSO years and also for weak to moderate ENSO events, although significant seasonal rainfall anomalies are observed over the USAPI, precipitation forecast skill by empirical model is low. Reasons may be manifold including: *a)* nonlinear relationship between ENSO SST and precipitation is not incorporated, *b)* details in the space-time evolution of SST during different flavours of ENSO are not properly accounted for, and *c)* SST anomalies other than ENSO may be responsible for rainfall variations. A prediction system based on a fully coupled dynamical model may overcome some of the above limitations.

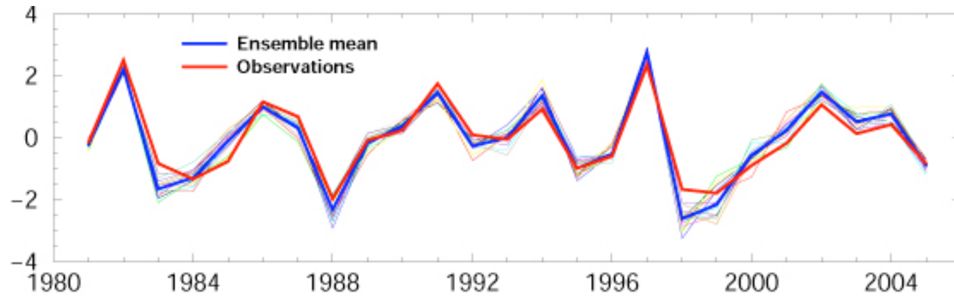
While past studies have examined the skill of SST anomalies over the equatorial Pacific, we evaluated CFS' ability in hindcasting, and forecasting: (i) tropical and regional precipitation anomalies; (ii) different flavours of El Niño and their associated regional response; and (iii) the teleconnection between the tropical Pacific and Indian Ocean (TIO). The suite of verification methods employed also provided uncertainty measures (error) associated with the hindcast and forecast skills.

CFS has ACC values higher than 0.8 (up to 7 month lead) in predicting tropical central to eastern Pacific SST anomalies, and for all the seasons except for boreal summer (Sooraj et al. 2010). CFS's skill in hindcasting three Niño indices, representing Nino 3.4 (5^oS-5^oN, 190^oE-240^oE), Nino 4 (warm pool (WP) El Nino events, SST averaged over 5^oS-5^oN, 160^oE-210^oE), and Nino 3 (cold tongue (CT) El Nino events, SST averaged over 5^oS-5^oN, 210^oE-270^oE) are shown in Figures 1a-c. While the mechanisms responsible for the different flavours of El Niño may be different and complex, and their regional and global impact may differ, CFS demonstrates high skill in capturing phase and amplitude of SST anomalies associated with all the Nino indices. For example, at 0 month lead, the warming associated with WP events (1990-91; 1994-95; 2002-03 and 2004-05) is aptly hindcast with minimum spread among the ensemble members (Fig. 1b) with an over-all ACC of 0.95 and signal to noise ratio greater 5.0. At 7 month lead time, while the ACC drops to 0.77 for WP events, it remains high at 0.9 for CT events (fig. not shown). An examination of winter (DJF) spatial distribution of SST anomalies during individual WP events indicates that the model is successful in capturing the local maxima around the dateline (Sooraj et al. 2010).

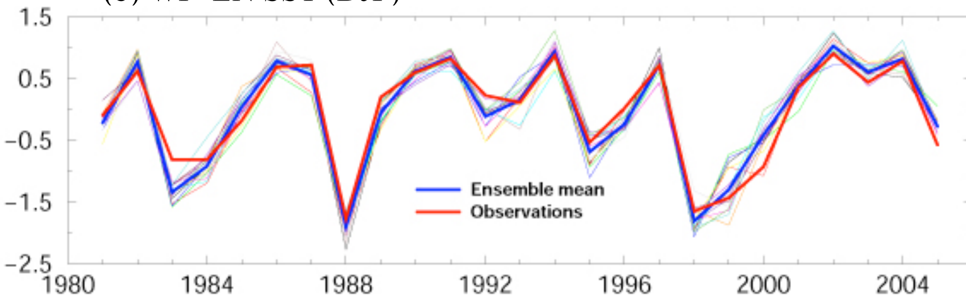
Over the equatorial Pacific, skill for the precipitation anomaly is higher during boreal winter (Fig. 1d), and following spring, and is marginal for other seasons (Sooraj et al. 2010). The model's ability is hindcasting equatorial Pacific heating anomalies is also reflected in its high skill in hindcasting SST and precipitation anomalies over southwest Indian Ocean, and subsequently, rainfall anomalies over the USAPI. The model shows skill (up to about 6 month lead) in hindcasting seasonal precipitation anomalies over south and west Pacific Island regions but the skill over the Hawaiian Islands is high only during very strong ENSO episodes, and is limited to 1-2 month lead (Sooraj et al. 2010).

Figure 2 summarizes the over-all skill (both deterministic and probabilistic) of CFS in hindcasting seasonal rainfall anomalies over the USAPI. The left panels (Figs. 2a-c) are scatter diagrams between ACC and HSS, and the right panels (Figs. 2d-f) are between ACC and RPSS, respectively. Over the west Pacific region, rainfall hindcast for boreal fall season has negative ACC, RPSS and low HSS values, and thus appears not useful. But hindcasting winter rainfall variations have the highest skill followed by spring and summer. For south Pacific region, for leads 0 to 4 months hindcasting winter and spring rainfall variations for which all scores converge have higher confidence. Here too, hindcasting the summer precipitation anomalies are less skilful. For the Hawaiian region, at shorter leads and for all seasons except fall, rainfall hindcast is skilful and probably useful too. Encouraged by the hindcast performance, we are examining the skill for the real-time forecast for the period 2006-2009. The results from these comprehensive diagnostics performed are available in Sooraj et al. 2010 (manuscript submitted).

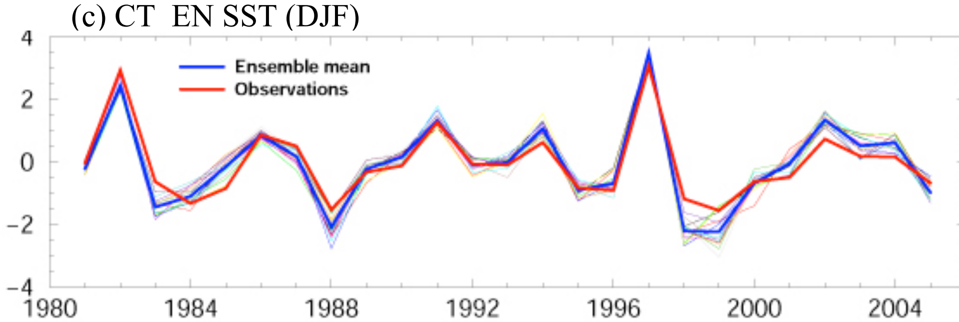
(a) Nino3.4 SST (DJF)



(b) WP EN SST (DJF)



(c) CT EN SST (DJF)



(d) Equatorial Pacifc rain (DJF)

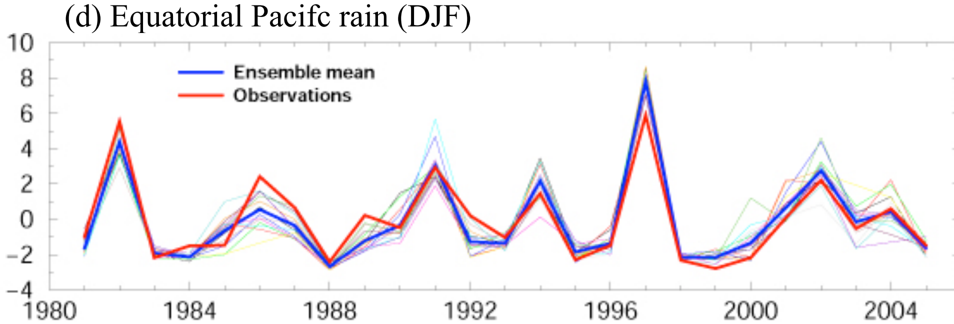


Figure 1: (a-c) Temporal evolution of December through February average (DJF) SST anomalies (^{o}C) hindcast by CFS at lead 0-month. Ensemble mean (blue), all 15 individual members (different colors) and observations (red) are shown for three regions: (a) Nino3.4 (5^{o}S-5^{o}N, 190^{o}E-240^{o}E); (b) Warm pool El Nino (WP_EN; 5^{o}S-5^{o}N, 160^{o}E-210^{o}E); (c) Cold Tongue El Nino (CT_EN; 5^{o}S-5^{o}N, 210^{o}E-270^{o}E). (d) same as (a) but for equatorial Pacific rainfall anomalies (mm/day) averaged over (10^{o}S-5^{o}N, 170^{o}E-250^{o}E).

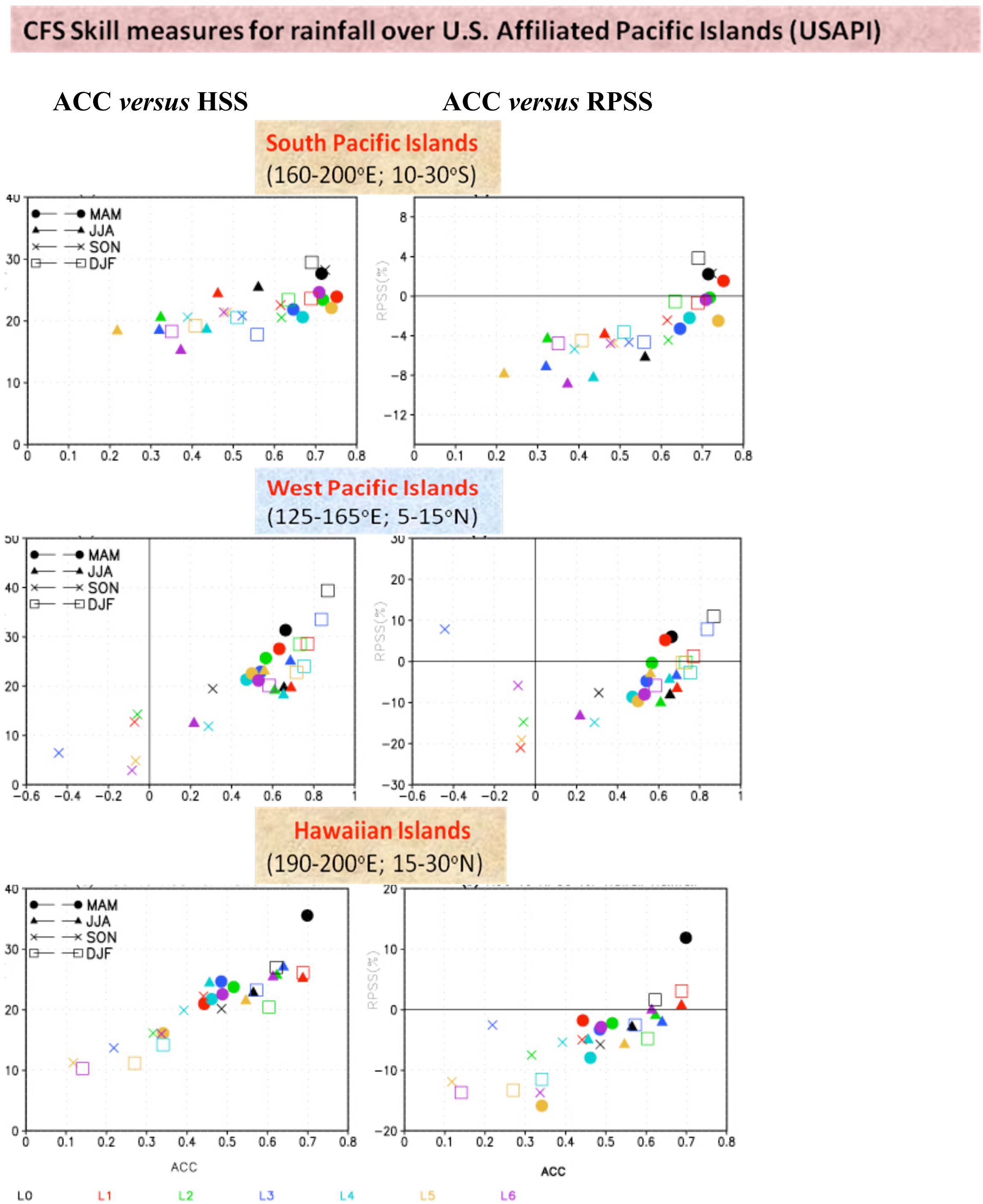


Figure 2: (left panels) Scatter plots between anomaly correlation coefficient (ACC) and Heidke skill scores (HSS) , and (right panels) scatter plots between ACC and Rank Probability skill score (RPSS) over three regions of the USAPI. The results are four standard seasons, and for all lead time forecast (0 – 6 months) shown in different colors.

3. Highlights of accomplishments

- PI (Annamalai) visited CPC, NOAA during the third week of January 2010 and discussed the various results of the project with Drs. Arun Kumar (Co-PI), Hui Wang (CPC), and Wanqiu Wang. The CPC personnel appraised CFS's ability for the real-time forecast in the tropics during 2005-08, the MJO simulation, and the new CFS.

- PI (Mark Lander) visited University of Hawaii during the second week of January 2010. UH personnel appraised Mark of the latest results, and appreciated his comments on the analysis over the west Pacific islands. Mark is examining the ability of CFS in hindcasting the "weather aspects" that make up the seasonal rainfall anomalies over the west Pacific islands.

- A 15-member ensemble monthly actual forecast data for the period 2006-09 was transferred from CPC to UH in February 2010. We are making detailed diagnostics now.

- A manuscript based on the diagnostics of the CFS hindcasts has been written up and submitted for publication

4. Publications

Sooraj, K.P., H. Annamalai, A. Kumar and H. Wang, 2010: A comprehensive assessment of CFS hindcast and forecast skills over the tropics (manuscript submitted).

5. PIs contact information

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